CLAIMS

1. An optical signal processing method including the steps of performing predetermined signal processing on a pulse train of signal light having a first wavelength according to control light having a pulse train having a second wavelength different from the first wavelength, by using an optical signal processor including an optical nonlinear device having an input-to-output characteristic with predetermined periodicity with respect to light intensity, and outputting a resultant signal light.

2. An optical signal processing method including the steps of performing predetermined optical logic operation processing on a pulse train of signal light having a first wavelength, by making use of one of (a) a plurality of control lights each having a pulse train having a second wavelength different from the first wavelength and (b) control light having a pulse train having a plurality of wavelengths different from the first wavelength, by using an optical signal processor including an optical nonlinear device having an input-to-output characteristic with periodicity corresponding to a predetermined optical logic operation with respect to light intensity, and outputting a resultant signal light.

3. The optical signal processing method as claimed in claim 1 or 2,

wherein said optical encoder includes a first optical nonlinear device and has a first input end for inputting the pulse train of the signal light, a second input end for inputting the pulse train of the control light, and an output end for outputting a pulse train of optically-encoded signal light.

4. An optical signal processing method including the steps of optically encoding a pulse train of signal light having a first wavelength according to control light which has a second wavelength different from the first wavelength and a pulse train of an optically sampled optical analog signal, by using a plurality of optical encoders each of which includes optical nonlinear devices having input-to-output characteristics with different periodicities with respect to light intensity, respectively, and outputting a

plurality of pulse trains of optically-encoded signal light from said respective optical encoders.

5. The optical signal processing method as claimed in claim 4,

wherein said plurality of optical encoders are "N" optical encoders each having an input-to-output characteristic with a period of $T/2^{(N-2)}$, where "N" is a natural number (N = 1, 2, 3...) indicating a quantifying bit number.

6. An optical signal processing method including the steps of decoding a pulse train of a multi-level optical signal having a first wavelength into a plurality of binary optical signals according to control light having a pulse train having a second wavelength different from the first wavelength, by using a plurality of optical signal processors including optical nonlinear devices having input-to-output characteristics with different periodicities with respect to light intensity, and outputting the plurality of binary optical signals.

7. The optical signal processing method as claimed in any one of claims 4 to 6,

wherein each of said plurality of optical encoders includes a first optical nonlinear device and has a first input end for inputting the pulse train of the signal light, a second input end for inputting the pulse train of the control light, and an output end for outputting a pulse train of optically-encoded signal light.

8. The optical signal processing method as claimed in any one of claims 1 to 7,

wherein said first optical nonlinear device is a nonlinear optical loop mirror.

9. The optical signal processing method as claimed in any one of claims 1 to 7,

wherein said first optical nonlinear device is a Kerr shutter which utilizes an optical Kerr effect of a nonlinear optical effect.

10. The optical signal processing method as claimed in any one of

claims 1 to 7,

wherein said first optical nonlinear device is a waveguide-type Mach-Zehnder interferometer.

11. An optical signal processing device comprising signal processing means for performing predetermined signal processing on a pulse train of signal light having a first wavelength according to control light having a pulse train having a second wavelength different from the first wavelength, by using an optical signal processor including an optical nonlinear device having an input-to-output characteristic with predetermined periodicity with respect to light intensity, and for outputting a resultant signal light.

12. An optical signal processing device comprising operating means for performing predetermined optical logic operation processing on a pulse train of signal light having a first wavelength, by making use of one of (a) a plurality of control lights each having a pulse train having a second wavelength different from the first wavelength and (b) control light having a pulse train having a plurality of wavelengths different from the first wavelength, by using an optical signal processor including an optical nonlinear device having an input-to-output characteristic with periodicity corresponding to a predetermined optical logic operation with respect to light intensity, and for outputting a resultant signal light.

13. The optical signal processing device as claimed in claim 11 or 12,

wherein said optical encoder includes a first optical nonlinear device and has a first input end for inputting the pulse train of the signal light, a second input end for inputting the pulse train of the control light, and an output end for outputting a pulse train of optically-encoded signal light.

14. An optical signal processing device comprising optical encoding means for optically encoding a pulse train of signal light having a first wavelength according to control light which has a second wavelength different from the first wavelength and a pulse train of an optically sampled optical analog signal, by using a plurality of optical encoders each of which

includes optical nonlinear devices having input-to-output characteristics with different periodicities with respect to light intensity, respectively, and for outputting a plurality of pulse trains of optically-encoded signal light from said respective optical encoders.

15. The optical signal processing device as claimed in claim 14,

wherein said plurality of optical encoders are "N" optical encoders each having an input-to-output characteristic with a period of $T/2^{(N-2)}$, where "N" is a natural number (N = 1, 2, 3...) indicating a quantifying bit number.

16. An optical signal processing device comprising multi-level decoding means for decoding a pulse train of a multi-level optical signal having a first wavelength into a plurality of binary optical signals according to control light having a pulse train having a second wavelength different from the first wavelength, by using a plurality of optical signal processors including optical nonlinear devices having input-to-output characteristics with different periodicities with respect to light intensity, and for outputting the plurality of binary optical signals.

17. The optical signal processing device as claimed in any one of claims 14 to 16,

wherein each of said plurality of optical encoders includes a first optical nonlinear device and has a first input end for inputting the pulse train of the signal light, a second input end for inputting the pulse train of the control light, and an output end for outputting a pulse train of optically-encoded signal light.

18. The optical signal processing device as claimed in any one of claims 11 to 17,

wherein said first optical nonlinear device is a nonlinear optical loop mirror.

19. The optical signal processing device as claimed in any one of claims 11 to 17,

wherein said first optical nonlinear device is a Kerr shutter which

utilizes an optical Kerr effect of a nonlinear optical effect.

20. The optical signal processing device as claimed in any one of claims 11 to 17,

wherein said first optical nonlinear device is a waveguide-type Mach-Zehnder interferometer.

21. An optical signal processing method for optically analog-to-digital-converting an optically sampled optical analog signal into an optical digital signal, the method including the steps of:

optically encoding a pulse train of signal light having a first wavelength according to control light which has a second wavelength different from the first wavelength and a pulse train of an optically sampled optical analog signal, by using a plurality of optical encoders each including optical nonlinear devices having input-to-output characteristics with different periodicities with respect to the light intensity, and outputting a plurality of pulse trains of optically-encoded signal light from said respective optical encoders; and

performing optical threshold processing on the plurality of pulse trains of optically-encoded signal light to optically quantize the plurality of pulse trains of optically-encoded signal light, by using at least one of optical threshold processors each of which is connected to each of said optical encoders and includes a nonlinear optical device having a nonlinear input-to-output characteristic with respect to light intensity, and outputting optically quantized pulse trains as optical digital signals.

22. The optical signal processing method as claimed in claim 21, further including the steps of optically sampling an optical analog signal at a predetermined sampling frequency, and outputting an optically sampled optical analog signal, prior to the optically encoding step.

23. The optical signal processing method as claimed in claim 21 or 22,

wherein said plurality of optical encoders are "N" optical encoders each having an input-to-output characteristic with a period of $T/2^{(N-2)}$, where "N"

is a natural number (N = 1, 2, 3...) indicating a quantifying bit number.

24. The optical signal processing method as claimed in any one of claims 21 to 23,

wherein the optically encoding step includes a step of optically quantizing each of the pulse trains of optically-encoded signal light, by using one of a single optical threshold processor and a plurality of optical threshold processors connected in cascade to each other for optically quantizing a pulse train of inputted signal light.

25. The optical signal processing method as claimed in any one of claims 21 to 24,

wherein each of said optical encoders includes a first optical nonlinear device and has a first input end for inputting the pulse train of the signal light, a second input end for inputting the pulse train of the control light, and an output end for outputting a pulse train of optically-encoded signal light.

26. The optical signal processing method as claimed in any one of claims 21 to 25,

wherein each of said optical threshold processors includes a second optical nonlinear device and has a first input end for inputting one of continuous light of predetermined carrier wave light and a pulse train of the predetermined carrier wave light, a second input end for inputting the pulse train of optically encoded signal light, and an output end for outputting the optically-quantized pulse train.

27. The optical signal processing method as claimed in any one of claims 21 to 25,

wherein each of said optical threshold processors includes a second optical nonlinear device and has an input end for inputting one of continuous light of predetermined carrier wave light and a pulse train of the predetermined carrier wave light, and an output end for outputting the optically-quantized pulse train.

28. The optical signal processing method as claimed in any one of claims 21 to 27,

wherein said first optical nonlinear device is a nonlinear optical loop mirror.

29. The optical signal processing method as claimed in any one of claims 21 to 27,

wherein said first optical nonlinear device is a Kerr shutter which utilizes an optical Kerr effect of a nonlinear optical effect.

30. The optical signal processing method as claimed in any one of claims 21 to 27,

wherein said first optical nonlinear device is a waveguide-type Mach-Zehnder interferometer.

31. The optical signal processing method as claimed in any one of claims 21 to 30,

wherein said second optical nonlinear device is a nonlinear optical loop mirror.

32. The optical signal processing method as claimed in any one of claims 21 to 30,

wherein said second optical nonlinear device is a Kerr shutter which utilizes an optical Kerr effect of a nonlinear optical effect.

33. The optical signal processing method as claimed in any one of claims 21 to 30,

wherein said second optical nonlinear device is a waveguide-type Mach-Zehnder interferometer.

34. An optical signal processing device for optically analog-to-digital-converting an optically sampled optical analog signal into an optical digital signal, said device comprising:

optically encoding means for optically encoding a pulse train of signal light having a first wavelength according to control light which has a second wavelength different from the first wavelength and has a pulse train of an

optically sampled optical analog signal, by using a plurality of optical encoders each including optical nonlinear devices having input-to-output characteristics with different periodicities with respect to the light intensity, and outputting a plurality of pulse trains of optically-encoded signal light from said respective optical encoders; and

optically quantizing means for performing optical threshold processing on the plurality of pulse trains of optically-encoded signal light to optically quantize the plurality of pulse trains of optically-encoded signal light, by using at least one of optical threshold processors each of which is connected to each of said optical encoders and includes a nonlinear optical device having a nonlinear input-to-output characteristic with respect to light intensity, and outputting optically quantized pulse trains as optical digital signals.

35. The optical signal processing device as claimed in claim 34, further comprising optically sampling means for optically sampling an optical analog signal at a predetermined sampling frequency, and for outputting an optically sampled optical analog signal, at the previous stage of said optically encoding means.

36. The optical signal processing device as claimed in claim 34 or 35,

wherein said plurality of optical encoders are "N" optical encoders each having an input-to-output characteristic with a period of $T/2^{(N-2)}$, where "N" is a natural number (N = 1, 2, 3...) indicating a quantifying bit number.

37. The optical signal processing device as claimed in any one of claims 34 to 36,

wherein said optically encoding means optically quantizes each of the pulse trains of optically-encoded signal light, by using one of a single optical threshold processor and a plurality of optical threshold processors connected in cascade to each other for optically quantizing a pulse train of inputted signal light.

38. The optical signal processing device as claimed in any one of

claims 34 to 37,

wherein each of said optical encoders includes a first optical nonlinear device and has a first input end for inputting the pulse train of the signal light, a second input end for inputting the pulse train of the control light, and an output end for outputting a pulse train of optically-encoded signal light.

39. The optical signal processing device as claimed in any one of claims 34 to 38,

wherein each of said optical threshold processors includes a second optical nonlinear device and has a first input end for inputting one of continuous light of predetermined carrier wave light and a pulse train of the predetermined carrier wave light, a second input end for inputting the pulse train of optically encoded signal light, and an output end for outputting the optically-quantized pulse train.

40. The optical signal processing device as claimed in any one of claims 34 to 38,

wherein each of said optical threshold processors includes a second optical nonlinear device and has an input end for inputting one of continuous light of predetermined carrier wave light and a pulse train of the predetermined carrier wave light, and an output end for outputting the optically-quantized pulse train.

41. The optical signal processing device as claimed in any one of claims 34 to 40,

wherein said first optical nonlinear device is a nonlinear optical loop mirror.

42. The optical signal processing device as claimed in any one of claims 34 to 40,

wherein said first optical nonlinear device is a Kerr shutter which utilizes an optical Kerr effect of a nonlinear optical effect.

43. The optical signal processing device as claimed in any one of

claims 34 to 40,

wherein said first optical nonlinear device is a waveguide-type Mach-Zehnder interferometer.

44. The optical signal processing device as claimed in any one of claims 34 to 43,

wherein said second optical nonlinear device is a nonlinear optical loop mirror.

45. The optical signal processing device as claimed in any one of claims 34 to 43,

wherein said second optical nonlinear device is a Kerr shutter which utilizes an optical Kerr effect of a nonlinear optical effect.

46. The optical signal processing device as claimed in any one of claims 34 to 43,

wherein said second optical nonlinear device is a waveguide-type Mach-Zehnder interferometer.

47. A nonlinear optical loop mirror comprising an optical fiber, a photo-coupler, control-light input means for inputting a control light signal to said optical fiber, and a nonlinear medium placed on an optical path of said optical fiber,

wherein said photo-coupler is connected so as to branch an input optical signal inputted from an optical-signal input end into two optical signals and to output the optical signals to both ends of said optical fiber and connected so as to branch and output optical signals outputted from the both ends of said optical fiber to said optical-signal input end and an optical-signal output end, respectively,

wherein said nonlinear optical loop mirror adjusts a phase difference between optical signals inputted to the both ends of said optical fibers according to power of the control light signal so as to control power of the output optical signal outputted from said optical-signal output end, and

wherein said nonlinear optical loop mirror suppresses a parametric

gain caused among the respective branched optical signals and the control light signal, so that a ratio of the power of the output optical signal to the maximum value thereof becomes equal to or smaller than a predetermined threshold value when a difference between phase shifts caused to the respective branched optical signals is set to $2n\pi$ (where "n" is an integer equal to or larger than 1), where the phase shifts are caused by cross-phase modulation (XPM) generated among the respective branched optical signals and the control light signal.

48. The nonlinear optical loop mirror as claimed in claim 47, wherein a relationship of $G<2Tth+1$ is set to be satisfied, where "G" is a ratio of amplification of the optical signal propagating in the same direction as that of the control light signal, where the amplification is caused by the parametric gain, and "Tth" is a ratio of the predetermined threshold value to the maximum value of the output optical signal.

49. The nonlinear optical loop mirror as claimed in claim 47, wherein one of the input optical signal and the control light signal is inputted after passing through an optical delay line, so that pulses of the optical signals and pulses of the control light signal are superimposed on each other over a predetermined range of said nonlinear medium.

50. The nonlinear optical loop mirror as claimed in claim 47, wherein polarization states of the optical signals and the control light signal are substantially identical to each other in said optical fiber and said nonlinear medium.

51. The nonlinear optical loop mirror as claimed in claim 48, wherein the predetermined threshold value is a threshold value required for quantization and encoding processings for optical analog-to-digital conversion.

52. The nonlinear optical loop mirror as claimed in claim 48, wherein the predetermined threshold value is 3 dB.

53. The nonlinear optical loop mirror as claimed in claim 47,

wherein one of the following conditions is set to be satisfied:

(a) a dispersion value of said nonlinear medium is equal to or smaller than the minimum dispersion value of dispersion values when the parametric gain caused among the optical signals and the control light signal is equal to or larger than a predetermined value; and

(b) a dispersion value of said nonlinear medium is equal to or larger than the maximum dispersion value of dispersion values when the parametric gain caused among the optical signals and the control light signal is equal to or larger than a predetermined value.

54. The nonlinear optical loop mirror as claimed in claim 47,

wherein a wavelength difference between the control light signal and the input optical signal is larger than the maximum wavelength difference which cause a parametric gain equal to or larger than a predetermined value among the optical signals and the control light signal.

55. The nonlinear optical loop mirror as claimed in claim 48,

wherein an absolute value of a product of a wavelength difference between the control light signal and the optical signals, and a dispersion value of said nonlinear medium is equal to or smaller than a value which suppress walk-off and set a phase shift difference between the branched optical signals due to cross-phase modulation (XPM) caused among the respective optical signals and the control light signal to be equal to or larger than 2π.

56. The nonlinear optical loop mirror as claimed in claim 48,

wherein a power value of the output optical signal is processed as "0" in an optical analog-to-digital conversion processing when a difference between phase shifts caused to the respective branched optical signals is $2n\pi$ (where "n" is an integer equal to or larger than 1), where the phase shifts are generated by cross-phase modulation (XPM) caused among the respective branched optical signals and the control light signal.

57. The nonlinear optical loop mirror as claimed in claim 53,

wherein a dispersion characteristic of said nonlinear medium has a normal dispersion characteristic, at a wavelength of the control light signal.

58. The nonlinear optical loop mirror as claimed in claim 53,

wherein a dispersion characteristic of said nonlinear medium has an anomalous dispersion characteristic, at a wavelength of the control light signal.

59. The nonlinear optical loop mirror as claimed in claim 57,

wherein a relationship of $\lambda_0>\lambda_S>\lambda_C$ holds when a dispersion value "D" of said nonlinear medium differentiated with respect to a wavelength λ is positive ($dD/d\lambda>0$), at wavelengths of the input optical signal and the control light signal.

60. The nonlinear optical loop mirror as claimed in claim 57,

wherein a relationship of $\lambda_0<\lambda_S<\lambda_C$ holds when a dispersion value "D" of said nonlinear medium differentiated with respect to a wavelength λ is negative ($dD/d\lambda<0$), at wavelengths of the input optical signal and the control light signal.

61. A nonlinear optical loop mirror comprising an optical fiber, a photo-coupler, control-light input means for inputting a control light signal to said optical fiber, and a nonlinear medium placed on an optical path of said optical fiber,

wherein said photo-coupler is connected so as to branch an input optical signal inputted from an optical-signal input end into two optical signals and to output the optical signals to both ends of said optical fiber and connected so as to branch and output optical signals outputted from the both ends of said optical fiber to said optical-signal input end and an optical-signal output end,

wherein said nonlinear optical loop mirror adjusts a phase difference between optical signals inputted to the both ends of said optical fibers according to power of the control light signal so as to control power of the output optical signal outputted from said optical-signal output end, and

wherein a dispersion characteristic of said nonlinear medium has a normal dispersion characteristic, at a wavelength of the control light signal.

62. The nonlinear optical loop mirror as claimed in claim 61,

wherein one of the following conditions is set to be satisfied:

(a) a dispersion value of said nonlinear medium at a wavelength of the control light signal is equal to or smaller than -0.62 ps/nm/km and a wavelength difference between the input signal light and the control light is equal to or larger than 16 nm; and

(b) a dispersion value of said nonlinear medium at a wavelength of the control light signal is equal to or smaller than -0.315 ps/nm/km and a wavelength difference between the input signal light and the control light is equal to or larger than 20 nm.

63. The nonlinear optical loop mirror as claimed in claim 62,

wherein polarization states of the optical signals and the control light signal are substantially identical to each other in said optical fiber and said nonlinear medium.

64. A nonlinear optical loop mirror comprising an optical fiber, a photo-coupler, control-light input means for inputting a control light signal to said optical fiber, and a nonlinear medium placed on an optical path of said optical fiber,

wherein said photo-coupler is connected so as to branch an input optical signal inputted from an optical-signal input end into two optical signals and to output the optical signals to both ends of said optical fiber and connected so as to branch and output optical signals outputted from the both ends of said optical fiber to said optical-signal input end and an optical-signal output end,

wherein said nonlinear optical loop mirror adjusts a phase difference between optical signals inputted to the both ends of said optical fibers according to power of the control light signal so as to control power of the output optical signal outputted from said optical-signal output end,

wherein a difference between phase shifts caused to the respective optical signals, due to cross-phase modulation (XPM) caused between the respective optical signals and the control light signal, is equal to or larger than 2π.

65. The nonlinear optical loop mirror as claimed in claim 64,

wherein said nonlinear medium has a normal dispersion characteristic, at a wavelength of the control light signal.

66. The nonlinear optical loop mirror as claimed in claim 64,

wherein said nonlinear optical loop mirror suppresses a parametric gain caused among the respective branched optical signals and the control light signal, so that a ratio of the power of the output optical signal to the maximum value thereof becomes equal to or smaller than a threshold value for optical analog-to-digital conversion when a difference between phase shifts caused to the respective branched optical signals is set to $2n\pi$ (where "n" is an integer equal to or larger than 1), where the phase shifts are caused by cross-phase modulation (XPM) generated among the respective branched optical signals and the control light signal.

67. The nonlinear optical loop mirror as claimed in claim 64,

wherein polarization states of the optical signals and the control light signal are substantially identical to each other in said optical fiber and said nonlinear medium.

68. A method for designing a nonlinear optical loop mirror comprising an optical fiber, a photo-coupler, control-light input means for inputting a control light signal to said optical fiber, and a nonlinear medium placed on an optical path of said optical fiber,

wherein said photo-coupler is connected so as to branch an input optical signal inputted from an optical-signal input end into two optical signals and to output the optical signals to both ends of said optical fiber and connected so as to branch and output optical signals outputted from the both ends of said optical fiber to said optical-signal input end and an optical-

signal output end,

wherein said nonlinear optical loop mirror adjusts a phase difference between optical signals inputted to the both ends of said optical fibers according to power of the control light signal so as to control power of the output optical signal outputted from said optical-signal output end, and

wherein the method including the steps of:

a first step of determining a transfer function and a period (ϕ_{max}) of the transfer function, the transfer function being expressed as a relationship of power of an input optical signal with respect to power of an output optical signal;

a second step of determining a threshold value of the output optical signal suitable for optical signal processing;

a third step of provisionally determining a nonlinearity constant and a dispersion characteristic of said nonlinear medium, and a wavelength and a peak power of the control light signal;

a fourth step of judging whether or not a phase shift reaches the period ϕ_{max}, and proceeding to a fifth step when the phase shift reaches the period ϕ_{max}, while returning to the third step when the phase shift does not reach the period ϕ_{max}; and

the fifth step of judging whether or not a relationship of $G<2Tth+1$ is satisfied, where "G" is a ratio of amplification of the optical signal propagating in the same direction as that of the control light signal, where the amplification is caused by the parametric gain, and "Tth" is a ratio of the predetermined threshold value to the maximum value of the output optical signal, and setting the nonlinearity coefficient and the dispersion characteristic of the nonlinear medium and the wavelength and the peak power of the control light signal which have been provisionally determined to a designing determined value when the relationship is satisfied, while returning to the third step when the relationship is not satisfied.

69. An optical signal conversion method including the steps of

branching an input optical signal into two optical signals (A) and (B), propagating the optical signal (A) in the same direction as that of a control light signal having a different wavelength so as to cause cross-phase modulation, and changing a phase shift difference between the optical signals (A) and (B) periodically with respect to change in power of the control light signal so as to change power of output optical signal resulted from interference between the optical signals (A) and (B),

wherein the method includes the steps of suppressing a parametric gain caused between the optical signal (A) and the control light signal, so that the power of the output optical signal when the phase shift difference is $2n\pi$ (where "n" is an integer equal to or larger than 1) is equal to or smaller than a threshold value for quantization and encoding processings for optical analog-to-digital conversion, with respect to the maximum value of the power of the output optical signal.